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Dependence of Temperature and Time during Heating of Tungsten Carbide-Based Hard Alloy Powders

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Introduction. The physico-mechanical and operational properties of hard alloys produced for various industries depend on many factors, the main of which are: production technology, physico-chemical composition of binding additives, size of carbide powders, cooking and cooling processes, level of internal stresses in phase components, structure of alloys.

This article presents the results of scientific research on the effect of temperature and time on the quality of hard alloys during the heating process of carbide powders.

Literature analysis. Annealing of hard alloys in vacuum furnaces is carried out in 2 stages: primary annealing and final annealing.

In the primary cooking, the powder is cleaned from the plasticizer added for good pressing and the primary structure of the powder is formed [1] (table 1).

1 table Primary baking procedure (same for all hard alloys).

No stage	initial temperature, ^{O}C	Finishing temperature, ^{O}C	Stage duration, min.
1	Room temperature	300	60
2	300	300	60
3	300	700	30
4	700	700	40
5	It is cooled along with the oven		

The purpose of the final baking process is to obtain the final structure, physical and mechanical composition, size and shape. The temperature of the final baking differs depending on the hard alloy brand and VK, TK, TTK groups [1] (table 2).

2 tables Order of the final baking stage of hard alloys with VK content (VK3 – VK-6 - VK8).

No stage	initial temperature, ^{O}S	Finishing temperature, ^{O}S	Stage duration, min.
1	Room temperature	700	120
2	700	1200	60
3	1200	1200	20
4	1200	1300	20
5	1300	1300	20
6	1300	1380	20
7	1380	1380	20
8	It is cooled along with the oven		

The temperature deviation limit shown in the tables may differ by +10 ^{O}C in the upper limit and +20 $^{O\,C}$ in the intermediate value.

Hard alloy parts shrink during cooking. The standard calculated reduction is 18 ... 20 ... 22 %.

At the same time, it is not possible to control the quality of the prepared concrete, the physical and mechanical composition of the initial raw materials and rubber, and the shrinkage coefficient cannot be specified, the deviations can be + 10%.

If the reduction size of the baked part is 5...10% larger than the allowed dimensions of the drawing, it can be brought to the drawing size during the final baking at high temperatures or during repeated baking . In this process , it is allowed to increase the cooking temperature by 20...50 ^{O}C and the cooking time up to 40 minutes. To determine the exact limit of temperature and time, an experiment is carried out on 2 3 samples.

However, care should be taken when using this method, as increasing the baking temperature and baking time in the final baking will decrease the bending strength and slightly increase the hardness.

Results of scientific works. First, 20 grams of tungsten carbide powder is taken for 3 samples, and 2 ml of plasticizer is added and pressed with a force of 2 t/sm ^{2} (Fig. 1, samples a, b, c). For another sample, 15 grams of tungsten carbide powder is taken and 1.5 ml of plasticizer is added and pressed with a force of 2 t/sm ^{2} (Figure 1 d sample). The amount of plasticizer and the degree of pressing have a great impact on the quality of the final product [2,3]. Pressed samples were placed in a vacuum oven and a vacuum was created (Fig. 1).

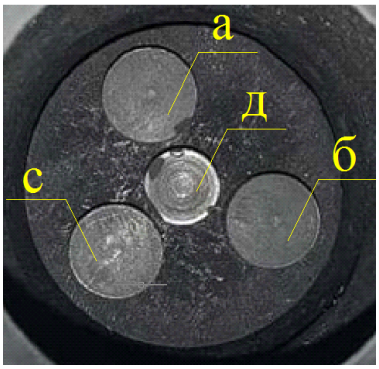


Figure 1. Samples placed in the oven.

In order to determine the effect of time on the baking process of the samples, the temperature inside the oven was quickly measured (table 3) instead of the time unit given in tables 1 and 2.

3 tables The final cooking method of hard alloys with VK content (VK 3 – VK 6 – VK 8).

No stage	initial temperature, ^{O}S	Finishing temperature, ^{O}S	Step duration , min.
1	Room temperature	4 00	3.58
2	4 00	5 00	3.01
3	5 00	9 00	9.55
4	900	1 1 00	5.56 _
5	1 100	1 15 0	4.02
6	1 15 0	1 38 0	7.28
7	1380	1380	20.30
8	It is cooled along with the oven		

As can be seen from the samples taken from the furnace, cracks appeared in the samples due to the temperature being waited too quickly (Fig. 2), one of the samples had many cracks and the sample crumbled during removal from the furnace.

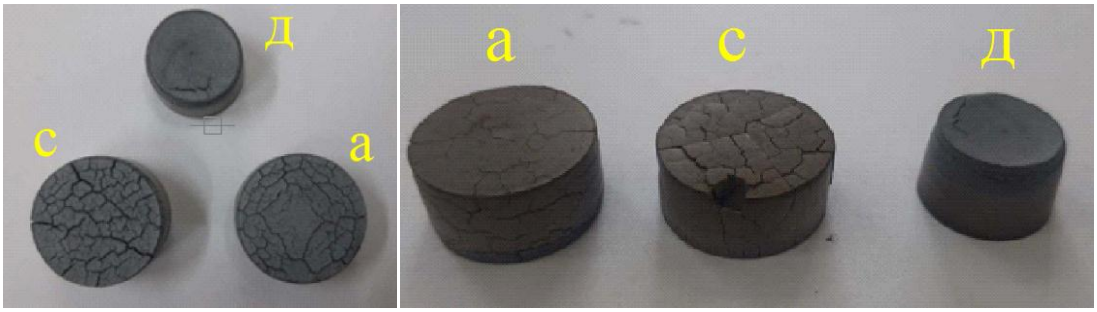


Figure 2. Samples taken from the furnace.

20 grams of tungsten carbide powder is taken for 1 sample and 2 ml of plasticizer is added and pressed with a force of 2 t/cm ^{2}. A vacuum environment was created by placing it in a vacuum oven and the primary cooking process began. The duration of the primary cooking process is given in Table 4 (Figure 3).

4 tables Primary sample cooking procedure (VK 6).

No stage	initial temperature, ^{O}S	Finishing temperature, ^{O}S	Stage duration, min.	Total, min.	Electric power consumption of the vacuum oven	
					Power, A	Tension , V
1	Room temperature	300	58.03	58.03	25...34	2.5...4
2	300	300	62.27	120.30	34	4
3	300	700	30.35	151.05	34...55	4...5.9
4	700	700	42.00	193.05	50	5
5	Cooled with the oven				0	0

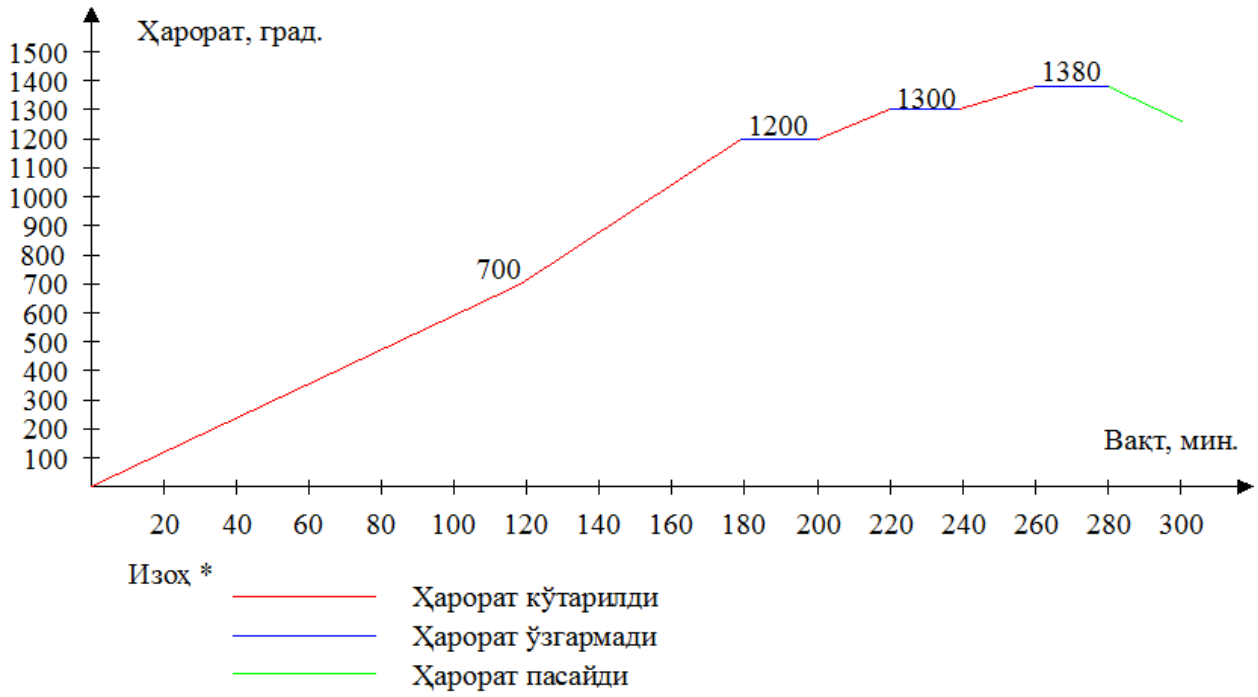
3 pictures. Graph of primary baking of hard alloy sample.

The primary cooking process was carried out at 193 min for 5 seconds and the vacuum oven was started. The furnace and samples were cooled together to room temperature.

Before starting the final decomposition A vacuum was again created in the furnace and the final decomposition process began. The duration of the final cooking process is given in table 5 (4 pictures).

5 tables Sample final cooking procedure (VK 6).

No stage	initial temperature, ^{O}S	Finisher temperature , ^{O}S	Stage duration , min.	Total, min.	Electric power consumption of the vacuum oven	
					Power , A	Tension , V
1	Room temperature	700	1 18.54	118.54	25...55	2.5...5
2	700	1200	6 1.01	179.55	65...70	6
3	1200	1200	20.03 _	199.58	70	6.1
4	1200	1300	19.59	219.57	80...84	7
5	1300	1300	19.23	239.20	84	7
6	1300	1380	21.03	260.23	86...96	8.1
7	1380	1380	2 0.59	281.22	96	8.1
8	Cooled with the oven				0	0



4 pictures. Finishing baking graph of a hard alloy sample.

The final baking process was carried out for 281 minutes and 22 seconds and the vacuum oven was started. The furnace and samples were cooled together to room temperature.

The samples were removed from the furnace, and no cracks were observed in the sample (Figure 5). The shrinkage of the specimen decreased from 20 mm to 17.4 mm (13 %) in diameter and from 10.5 mm to 8.9 mm (15.2 %) in height. This reduction is at the level of reduction set in the general account.

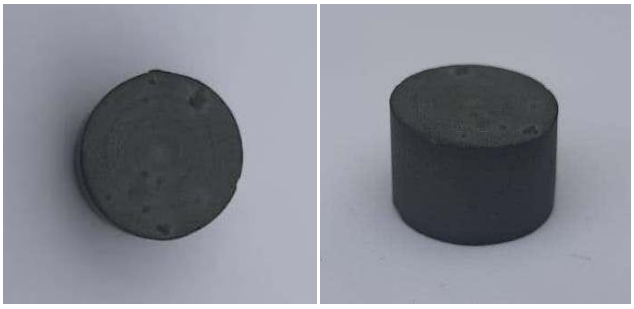


Figure 5. A sample from the oven.

Conclusion. Scientific and practical research has shown that the relationship between time and temperature in the process of baking hard alloys has a great impact on the quality of the part being baked (hardness, strength, ductility).

Slow temperature waiting for complete release of the plasticizer contained in the pressed sample, complete melting of cobalt, which is a binding element, and tungsten carbide together with the alloy form, 60 minutes at 300 ^{O} C in the primary baking stage, 40 minutes at 700 ^{O} C, and 1200 ^{O} C, 1300 ^{O} in the final baking · It is advisable not to change the temperature for 20 minutes at C, 1380 ^{O} C.

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